VOLUME XXIV NUMBER 4 WHOLE NUMBER 193

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS
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Director of the Dominion Astrophysical Observatory, Victoria, B.C.
J. PATTERSON
Director of the Meteorological Service of Canada, Toronto

R. MELDRUM STEWART
Director of the Dominion Observatory, Ottawa

PUBLISHED MONTHLY
(Ten numbers per year)

April, 1930

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL

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PLATE V

RALPH HAMILTON CURTISS
1880-1929

THE JOURNAL
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RALPH HAMILTON CURTISS
1880–1929

By DEAN B. MCLAUGHLIN

with Plate V

On Christmas Day, 1929, Professor Ralph Hamilton Curtiss, Head of the Department of Astronomy and Director of the University of Michigan Observatories, passed away after an attack of pleurisy which lasted a little less than a month. His death was a severe shock to his many friends and colleagues throughout the world,—the more so because he had passed the crisis several days earlier and high hopes were entertained for his recovery. But his severe illness had greatly weakened him and his death followed an unexpected heart attack. He is survived by his widow, Mary Welton Curtiss, and his brother, Professor David Raymond Curtiss.

Ralph Hamilton Curtiss was born February 8, 1880, at Derby, Connecticut. The family is of unmixed New England blood, the direct ancestors in all lines of descent having migrated to America prior to 1650. In 1892 his family moved to Redlands, California, where he followed his older brothers through high school, graduating with a high record at the age of sixteen. Financial circumstances made it necessary for him to work for a year before going to college.

He entered the University of California in 1897 and graduated in 1901 with an excellent record—attained, however, without loss of social contacts, for he engaged in several extra-curricular activities and was popular in his fraternity and with all who knew him. He was elected to Phi Beta Kappa in his junior year.

Under the guidance of E. P. Lewis, his firm foundation in physics and instrumental technique was laid. But under A. O. Leuschner he was attracted to astronomy, and about the beginning of his junior year he decided to devote his life to the study of the stars. Having completed the requirements for graduation by the middle of his senior year, he was able to spend the second semester on the journey to Sumatra as a member of the Lick Observatory expedition to the eclipse of 1901. This was an experience the memory of which he always treasured.

From 1901 to 1904 he held a Lick Observatory fellowship, and he was Carnegie assistant there in the next year. Spending alternate semesters at Lick Observatory and Berkeley, he obtained the degree of Doctor of Philosophy in 1905. At the Lick Observatory he profited much by his association with W. W. Campbell and W. J. Hussey, and from his friendship with the latter the future programme of the University of Michigan Observatory developed.

In 1905 he was called to the Allegheny Observatory, where he designed and adjusted the Mellon spectrograph and had much to do with the planning of the observing programme. There he also carried on a monumental piece of work on the spectrum of Beta Lyrae, from which his later studies of spectra of class Be developed at Ann Arbor.

In 1907, Professor Hussey was able to add another member to the staff at Ann Arbor, and he chose Doctor Curtiss, then twenty-seven years of age. Appointed first as assistant professor, he was promoted to associate professor in 1911 and professor in 1918. He was also appointed assistant director of the observatory in 1911. During his first years at Michigan the 37½-inch reflector was constructed and Professor Curtiss made many suggestions and contributions to the design of that instrument. He designed the single-prism spectrograph and planned the observing programme which was begun in 1911 and is still continued. More recently a two-prism spectrograph was built according to his designs.

During the World War he taught navigation at Ann Arbor and at the Great Lakes Naval Training Station. He continued to give courses in this subject in the University until the year of his death.

When Professor Hussey died suddenly in the autumn of 1926, Professor Curtiss was well prepared to take over the directorship

of the observatory. Indeed he had several times been in full charge of the observatory during the absence of Professor Hussey at La Plata Observatory or in South Africa. During his administration as director, Professor Curtiss pushed forward the plans for a new observatory far from the almost untenable site in Ann Arbor. Only a few days before his death the University, on his recommendation, purchased land which he had examined and chosen as a site for the new observatory.

Under his direction also the student observatory was established. Many contributions were made by him to the design of the fifteen-inch pyrex reflector, which is now nearly ready for assembly. A self-registering microphotometer and a spectro-helioscope were added to the observatory equipment. Two additional volumes of observatory publications were prepared for the press. Plans for the construction, and later the administration, of the Lamont Hussey Observatory in South Africa occupied much of his time. He was intensely interested in this programme, and the last paper he completed for publication (which appears in the December, 1929, number of this journal) dealt with the separation limits of double stars.

Professor Curtiss married Mary Louise Welton of Ann Arbor in 1920. No couple could have been better suited to one another. Mrs. Curtiss took a keen interest in his researches and aided him by performing reductions and computations.

His chief programme of research was the study of stellar spectra of class B having emission lines, on which he published numerous papers, but his work was not confined to this field. At Lick Observatory he became interested in R Scuti, an interest which continued at Ann Arbor, where about two hundred spectrograms of this peculiar variable have been obtained, and he made many observations of its brightness. At the time of his death a thorough discussion of the light variations and of a part of the spectrographic data was in an advanced stage. He was always interested in the Cepheid problem, an interest which also dates from his studies at Lick Observatory, his dissertation for the doctorate being a study of the Cepheid W Sagittarii. A spectrographic study of Delta Cephei was far advanced at the time of his death. The Be stars led naturally through P Cygni to the novae, and an extensive

study which he made of the spectra of novae remains to be completed.

His position as an authority on stellar spectra is attested by the fact that he was chosen to prepare the section on Classification of Stellar Spectra for the Handbuch der Astrophysik. This piece of work was practically ready to go to press at the time of his death. Besides his spectrographic researches he made many observations of the light of bright variable stars, notably Beta Lyrae, Delta Cephei, and S Sagittae.

His bibliography contains fifty-five titles, not counting the numerous papers which he presented at scientific meetings and which are published only as abstracts. In reading his papers one is impressed with the painstaking thoroughness which characterized his work. He never "rushed into print"; his papers were finished productions, not only from the scientific standpoint, but from the literary as well.

But his influence on astronomy is more far-reaching than can be seen either in his published researches or in those which remain to be completed. The single-prism and two-prism spectrographs are permanent monuments to him and will serve for many years more in the study of stellar spectra. He was consulted in connection with the establishment of the Dominion Astrophysical Observatory, the new Perkins Observatory, and some smaller ones. His files of correspondence reveal many suggestions regarding instruments, methods, and theory, which he gave to his colleagues.

As a teacher he was very popular and greatly beloved; his lectures were well prepared and ably delivered, and his blackboard diagrams were models of clearness. He directed the thesis investigations of fifteen candidates for the doctorate degree; four of these are now carrying on active research in astronomy, one in physics, and most of the remainder are teaching astronomy, mathematics, or physics.

Among his other interests he took up seismology and designed small portable seismographs which he used for obtaining data in connection with certain suits for damages caused by vibrations. But this work proved time-consuming and he finally resolved to give it up completely, in spite of the high additional revenue it brought in. On one occasion he rejected a proposal to study

vibrations with compensation of fifty dollars per day, remarking in a letter to a colleague: "I'd rather be a poor astronomer than a rich consultation expert."

During his twenty-two years at the University of Michigan he took only one semester leave of absence. On that occasion, in 1926, he visited Yerkes, Lick, and Mount Wilson observatories, studying the spectra of novae and working on his section of the Handbuch der Astrophysik.

Professor Curtiss was a hard worker, but he did not slight his recreation. He was an ardent fisherman, and he once remarked that he had caught bass in over two hundred lakes in Michigan. Later he took up golf and became an excellent player. Only two months before his death he played his favourite course in par, scoring a hole-in-one on the 184-yard eighth hole.

He was a Fellow of the Royal Astronomical Society, a Councillor of the American Astronomical Society, member of the International Astronomical Union, American Association for Advancement of Science, American Seismological Society, American Association of University Professors, University of Michigan Research Club, Phi Beta Kappa (he was president of the Michigan Chapter in the year of his death), Sigma Xi, Gamma Alpha, Delta Tau Delta, and Kiwanis.

The almost innumerable expressions of sympathy to Mrs. Curtiss from astronomers and friends all over the world bear witness to the scientific distinction of Professor Curtiss and the affectionate regard in which he was held by his colleagues. His modesty and simplicity of character earned for him many friends. A fine sense of humour, unlimited patience both with small time-consuming details and with the deficiencies of others, and tolerance of opinions differing from his own, made him an ideal director and colleague to work for and with. He was always most generous in permitting members of the staff to initiate new observing programmes and research problems, for he believed thoroughly in encouraging individual initiative.

He worked practically to the end, even correcting some examination papers and dictating letters within two days of his death. During the last days he gave to Mrs. Curtiss instructions with regard to his unfinished researches. Through these there runs the

determination that the work which was his life should not cease with his earthly existence. His last requests may be summarized by two words: "Carry on!"

Thus he passed from among us, tragically cut off in the very prime of life and at the height of a brilliant career. But the distinction of his work will live long, and his name will remain associated with the new problems and the new phases of old "classical" problems which he opened up and which, alas, remain for others to attempt the solution.

> To you, from failing hands we throw
> The torch—be yours to hold it high!

How few there are who can hold it high! How few are fitted to comply with his last request to "Carry on"!

ASTROLOGY AND ITS INFLUENCE UPON THE DEVELOPMENT OF ASTRONOMY*

By Anton Pannekoek

In the history of the natural sciences certainly no other science occupies such an important and peculiar place as astronomy. This is, because it is the most ancient science. In those remote centuries of antiquity, when there was no trace of a systematic study of physics or chemistry, astronomy was already a highly developed discipline. To its great age the special importance of astronomy in the history of civilization is due. For the other sciences, history is confined almost entirely to the last three or four centuries; their development took place within the walls of universities and laboratories, far from the convulsions of social and political life. Their students were modern men, of our own kind, for whom the pursuing of scientific researches was a special profession, directed by the same accepted tradition as our own work.

With astronomy matters are different. Its history accompanies the development of mankind from its first beginnings. It goes back to ages in which social life had a structure quite different from that in modern times, in which society, state and church, religion, law and science were one unbroken unity, and in which human thinking and being was different from nowadays. Our predecessors were Babylonian priests and magicians, Greek philosophers, Arabian princes, mediaeval monks, Renaissance noblemen before they turned into modern university professors. For them the science of the stars stood not apart from their other opinions but was intimately interwoven with their philosophical and religious conception of life. In the 16th century the contest about astronomical truth was part of a struggle between world conceptions, and was deeply connected with the social struggles of that time. In this strife astronomy cleared the way for the freedom of scientific research generally.

If we now turn to the first beginnings of astronomy, which were coincident with the first beginnings of civilization, the question

*A lecture delivered before the Victoria Centre R.A.S.C. Sept. 17, 1929.

naturally arises,—what was its origin? What was the reason that these primitive people turned their eyes to the stars and began to observe them regularly? Was it admiration of the beauty of the heavens, was it the dawning impulse of study to find out the cause of the phenomena? No, it was the hard necessity of life that induced them to look at the sky, the practical needs connected with their labour and intercourse with other people. Two necessities chiefly imposed the study of astronomy upon them. The first was the need of orientation, when for purposes of commerce they had to travel through the trackless deserts or over the dangerous seas. The Arabs, when they travelled in their caravans through the burning sands, looked at the stars to keep their direction. The Polynesian sailors from the Australian islands in the Pacific used the rising and setting points of special stars as their compass and they had navigation schools where knowledge of these stars was taught. The Phoenicians and the Greeks, when crossing the Mediterranean sea, had the stars as their guides; in the Odyssey the goddess Kalypso tells Odysseus to keep the Bear always on his left hand when steering home. In this way such people became acquainted with many stars and constellations and their most common phenomena.

To this was added, as a second need, the necessity of time reckoning. Agriculture everywhere is bound to a period of a year, because sowing and harvesting always return at the same season or date of the year. These dates were determined in remote antiquity by the appearance or disappearance of certain stars. The most famous instance is the morning rising of Sirius, which for the ancient Egyptians announced the beginning of the Nile floods. In the old Greek poem of Hesiod the business of the whole year is connected with the stars; with the heliacal rising of Arcturus the grapes have to be picked, and when Orion and the Pleiades are setting in the morning the plough has to be put into use. With all the primitive tribes we find their agriculture, their hunting and fishing regulated by phenomena of the stars. In the course of the higher development of ancient society, with the rise and growth of cities and large empires, the need of chronology becomes more intense. For commercial life in the towns the hour of the day is needed; in Athens and other Greek towns it was found by shadow-

casting poles and gnomons. But also the days have to be counted and longer periods have to be measured. This was only possible by making use of the periods of the celestial bodies; and the moon especially presents itself for this purpose. With all peoples of antiquity, the Indians, Babylonians, Jews, Greeks, we find the moon calendar used; the period of the moon, the regular sequence of the first appearance of the fine crescent moon in the evening sky, its growth to first quarter, to full moon, at the same time coming up later and filling the whole night, then the decrease to last quarter till its disappearance after the last thin crescent before sunrise was seen,—this regular cycle of the moon's phases in the period of 29½ days was everywhere the first basis of chronology. "For regulating the time the moon has been created,"—this opinion we find written in many sacred books. Our month is a distorted tradition of the original lunar month, which always began with the appearance of the new moon crescent in the evening sky. Even to-day may we see in Mohamedan countries the priests in their high minarets watching the sky, in order to observe the moment this horn will first appear and to call out then the beginning of the new month. This important rôle of the moon in primitive societies was the origin of the moon worship.

With the establishment of this moon cycle, however, the calendar was not satisfactorily fixed, and it has further developed in different ways with different peoples. For us, who never have to care for time reckoning because we have our calendars made ready by the astronomers, years, and, if necessary, centuries in advance, we can hardly imagine what an important and difficult matter was the exact regulation of the calendar in ancient times and what a number of observations were necessary. It was a subject of continuous attention and concern for the priesthood, which had to take care of it; but just for this reason also, it added to their power. Perhaps one asks why such an exactitude was necessary, some days earlier or later would do no harm in those primitive societies. But we should not forget that in those times the people, the tribe, the state was at the same time a political and a spiritual and religious unity. Important events of society, the great agricultural performances, the beginning of the ploughing, the sowing or the harvesting were

great popular festivals and at the same time chief religious ceremonies, where offerings were presented to the gods. But as religious ceremonies they had to follow a strict ritual proceeding, the gods had to be served not carelessly but at the exact moment and in the exact prescribed way. The calendar was the chronological regulation of worship. Thus the moon calendar had to adapt itself to the economical life of the people, which was governed by the yearly cycle of seasons. There arose the practical problem of adapting the moon period of 29½ days to the solar year of 365 days. This chief problem of ancient chronology has been a mighty impulse to the study of astronomy, because it necessitated continual observation of the sky.

Twelve lunar months of 29½ days each, making a total of 354 days, fall 11 days short of the solar year. In the next year the beginning of each month occurs 11 days earlier, and in three years 33 days will be lost. To fix the same month to the same season always there is no other means than after two or sometimes three years to intercalate an additional month, number 13, by repeating the last month of the year. This was first done empirically. When in ancient Palestine the end of the twelfth month (in March) was approaching, the rabbis went out to the field to see whether the grain would be ripe and fit for the sickle within two weeks. For in the middle of the first spring month Nisan at full moon it would be Pascha, when an offering of the first crop was to be made. If now it was so early in the year that the grain would not be ripe, the month would be doubled and the beginning of the year postponed. In the same way the adaptation of the lunar months to the seasons of the solar year has originally taken place in other countries. Afterwards, as a result of centuries of practice, a regular rule founded upon better knowledge of the periods of the sun and moon was substituted for this irregular empirical proceeding. The highest development was reached in the 19-year period in which 12 ordinary and 7 enlarged years of 13 months were interchanged in a determinate way. This was reached in ancient Greece through the golden number of Meton, as well as in the old Babylonian and in the existing Jewish calendar.

So we find the science of astronomy in its first beginnings grow-

ing out of the necessities of practical life. But we know that not everything in society depends on practical usefulness. Where society develops to higher forms, where, by commerce or by the fertility of the soil an abundance of goods is produced above immediate needs, where a dominating or a wealthy class takes the direction of the more complicated social structure, there has grown up a more refined culture and more differentiated spiritual need, which themselves become new incentives to study and research. The history of astronomy presents an example of this. These beginnings of science, as a basis of travel and chronology, may be compared to a vigorous useful plant, firmly rooted in the soil of practical necessity. But now from it there blossoms, like a beautiful flower of luxury and fancy, astrology, the doctrine of the intimate connection between the course of the stars and the fate of mankind, which during dozens of centuries was the mightiest motive power of science and which exalted astronomy from a practical knowledge to the rank of a sublime doctrine.

Out of the primeval civilization of Babylon it was born, a mixture of primitive superstition and high mental aspiration. All primitive peoples believe in omens and sorcery, in prophesying and exorcisms. In the first stage of religion they saw the world around them full of spirits, good and evil ones, on whose sentiments and interposition the success of their work depended. So they tried to win their good will, or at least to know their intentions. Among other omens now and then, also, celestial phenomena—e.g., eclipses or shooting stars—were considered as indications of the future. But only in Babylon arose a firm and intimate connection between divination and the firmament.

Here, in the fertile plains of the Euphrates and the Tigris, already in pre-Babylonian times, large centralized empires arose, chiefly from the necessity of a general regulation of watercourse and water supply; besides, the military power of the princes' organized priesthood stood as the chief spiritual power. Their task of serving the gods included the fixing of dates for general ceremonies, the regulation of the calendar,—consequently the observation of the celestial phenomena.

When watching, in their wonderfully clear climate, the appear-

ance of the new moon in the evening sky or its rising and setting, for the exact times of the full moon sacrificial rites, their attention would be drawn to the constellations, regularly changing each month, and especially to those bright stars, the planets, wandering in quite irregular trails among the other stars, as travellers over a landscape. What was their meaning? The meaning of the sun's and moon's motion was obvious; one provided the change of seasons, the other regulated the time. Then these other luminaries must also have a meaning; they had to indicate the other regulations which the gods made for mankind on earth. Each of them was identified with one of the chief gods of their Pantheon. In this way in the mind of these priest-astronomers the conception arose of a world unity, where the phenomena of the sky were the prototype of the happenings on earth. They saw the seven light-gods, while quietly describing their irregular tracts through the stars, spinning the threads of destiny for the peoples and empires on earth. Now the attentive observations of the celestial phenomena became still more necessary than for the practical aim of the calendar; it was now a holy service of the gods, it was reading their messages to their servants, the priests, the kings and the other men.

In the large collection of clay tablets covered with cuneiform inscriptions which were dug up from the ruins of the library of Assurbanipal at Niniveh and which now are preserved at the British Museum and have been partly deciphered, we have an important source of information about these things. Here we may see how, among other omens, from the flying of birds, the barking of dogs, the livers of the victims, the appearance of the clouds, also the omens from the moon and the stars take an especially important place. Continually the astrologers from the chief cities are sending their reports to the king on what they have seen and what is the meaning of it. To show the character of these observations and explanations I cite some of them from the collection, published by Thompson.

"When the star of Marduk (here Mercury) appears in the beginning of the year the crops will grow well. Mercury appeared in the month of Nisan. The planet approached the star Li (Aldebaran); this means the king of Akkad will die. The star of Marduk was seen in the Bull, as far back as the Pleiades it returned; during a month it was visible; rain, showers and floods will occur."

"When there is a ring around the moon and Spica is in it, the king of Akkad will have a long life. The moon was surrounded by a river; great floods and cloudbursts will come; Spica is within the ring around the moon."

"Mars was in the region of Bel near the feet of Perseus; on the 26th of Airu I saw it high in the sky; to the king my lord I send the explanation. Mars approaches the Pleiades means: in Amurru is war; one kills another."

"This night the moon was surrounded by a ring, Jupiter and the Scorpion were within. If Jupiter is within a moon-fence the king of Akkad will be besieged. When the Scorpion is within a moon-fence the lions will murder and the traffic of the land will be inhibited."

We will, of course, not insist on these explanations; they were partly taken from the appearance, such as the comparison of a moon-halo with a besieged city or with a streaming river; partly from traditions of former events. The interesting fact is that astrology, in order to find a correlation with the irregular unexpectedness of events on earth, had to turn to these celestial bodies which show most irregularities in their appearance, not to the sun and the stars, but to the moon and the planets. So a regular and assiduous observation of the planets, which were of no use for calendar or travel, was secured; and this has been the foundation of the later development of astronomical science.

Of course a long time elapsed before this took place. During many centuries the priest-astrologers observed the planets, noted their motions in their reports, without thinking of deriving periods out of these observations. Moreover, this was not possible, as long as they did not have a regular and continuous counting of the years. But when such a counting was introduced, say 800 B.C., then soon a knowledge of the periods of the planets developed. Then they found the hidden regularities in what at first seemed quite irregular, and at last they reached a state of knowledge where they were able to predict the course of the moon and the planets with great precision. This perfection was reached nearly 400 or 300 B.C., in a time when Babylon was one of the capitals of the Persian empire.

By a thorough study of the clay tablets dug up from different sites Epping and Kugler have discovered the high precision of the modes of computation and numerical data which were used by the Babylonian astronomers during the following centuries in predicting the celestial phenomena. It must be remarked, however, that this high perfection of Babylonian astronomy was only numerical. Just because these astronomers were priests, bound to religious tradition, they have not conceived another world system than what is given by the ordinary every day appearance. Only after they handed on their knowledge to the Greeks did it become the basis of new cosmological systems.

Greek astronomy, before it came into contact with the Orient, had developed its chronology and a general knowledge of the chief stars. Because no mighty priesthood grew up in this land of separate independent townships and islands, religious tradition had not a paramount influence and philosophical speculations of laymen, travellers, merchants and landowners occupied themselves with the structure of the world. They surprise us by the boldness of their abstract conception and at the same time by the poverty of their observational facts. In these speculations, which found their climax in the grand world system developed by Aristotle, astrological believings find no place. This picture changes when, with the conquest of the Persian empire by Alexander, East and West came into contact. Babylonian collections of observations were sent to Greece, instruments such as had been used already at Babylon were introduced in Alexandria and other Hellenistic capitals in order to observe the stars. The periods found by Babylonian astronomers were now used by Hipparchus to build up his system of planetary epicycles. What had been mere numbers in Babylon, in the hands of the Greek astronomers became the elements and dimensions of geometrical orbits of the planets. By the combination of oriental richness of experimental facts and the Greek genius of abstract thought the golden age of ancient science was brought about.

Along with oriental science astrology now enters into the mind of the western peoples. Theophrastus, a pupil of Artistotle, wrote a work "On the Signs," in which he explains Chaldaean astrology, the stoics propagated its doctrine and in the Roman world it was

accepted by nearly every man of learning and culture. But here it assumed an entirely different character from what it had been in Babylon. In the old despotic empires of the Orient the stars of Marduk, of Ishtar and of the other great gods foretold the fate of states and princes, the happenings of importance for the whole country such as floods, harvest and war, but they did not take notice of the fate of the single ordinary men. In the citizens of Rome and Greece, however, a strong individualism had grown up, that did not ask after predictions on harvest and on politics but wanted to know the future of themselves. Horoscopy, the derivation of a person's fate from the position of the planets at his birth, now became the most important practice of astrology. In Babylon astrology had been a religious truth, so that nobody asked reasons. In the Roman empire the primitive religious beliefs had given way to a critical and sceptical state of mind; here each creed and each theory was discussed and so astrology had to be founded on logic and experience.

You smile at the idea that astrology should be founded on reasons from experience because from the standpoint of modern science we see it only as a superstition. If, however, we proceed from the general state of knowledge in those times we will see that it could bring forward for its support some facts of experience; it simply deduced too far reaching consequences from these facts—but so often did modern science. Let us look at the relations between the course of the heavenly bodies and the happenings on earth. First take the sun. For us the yearly alternation between heat and cold is an obvious effect of the changing height of the sun. But in the more southern countries the yearly period is not chiefly a change of temperature but an alternation of a wet and a dry season. When the complicated geophysical origin of these climatic peculiarities was not known the regular return of the rainy season was obviously connected with the presence of the sun in certain signs of the zodiac, which just by this reason bear the names of Waterman and Fishes. It was observed that storms, or excessive heat, or rains each year coincided with the rising or setting of certain stars; was it illogical to see in those stars the causes of these phenomena? Just in the same way the aborigines in some parts of Australia consider not the

sun but the Pleiades as the cause of the summer heat; for the sun they say shines all the year, but the Pleiades are only present in summer time. We may know better by the totality of our science but we cannot pretend that this is bad reasoning. Then for these ancient peoples was added the knowledge of a monthly period in physiological functions of the body and the phenomenon of the tides, which both pointed to an influence of the moon on earthly life. All this could give a firm certainty already of an intimate connection of celestial and earthly phenomena. If now at the occurrence of an extraordinary event, say a pestilence, there happened to be a conjunction of some planets or stars, a relation between the two events imposed itself at once upon the mind. We may remark that from one coincidence they should not derive a rule and that more caution in generalising should have been used; but then we have to consider the deep-rooted conviction of a unity of the whole world, which was the case in all astrological inferences. At that time heaven and earth were not so far apart as nowadays and men and the universe were more comparable and equally valued. Let us hear arguments from the astrologers themselves; I quote here the following reasons which Ptolemy gives in his great astrological work:

"We have here at once a thesis which is entirely evident and does not need a lengthy argumentation; a force that proceeds from the eternal region of the ether, propagates to everything that surrounds the earth, and is subjected to continual variations. The first elements below the moon, the fire and the air, are disturbed by the movement of the surrounding ether; in their unrest they draw with them the lower things, the water, the earth as well as the plants and the animals that originate from them. The sun which with the sky surrounds all the terrestrial things imposes upon them its fixed and permanent order. . . . The moon which is next to the earth influences all the earthly world in an obvious way; most animate and inanimate beings follow its changes; the rivers increase and decrease with the moon; as she rises and goes down the seas are moved by opposite streams and plants and animals feel in some of their parts or totally the influence of the increase or the decrease of the moon. Furthermore, the course of the stars is an omen to numerous phenomena in the air, such as heat, cold or wind. The relative situations of the stars are a cause of many variations, for by their combination the celestial bodies mix up their effects. The force of the sun surpasses, after the structure of the world, the other stars, but still they can add to or subtract from what it does. The moon shows this most obviously in its different phases; for the other stars, we cannot verify this so often and in such a clear way."

I suppose many are astonished to hear that this is said by Ptolemy, the most famous astronomer of antiquity. That is because modern writers are in the habit of speaking of old astrology as a regrettable aberration of the human mind, and of trying to wash the famous astronomers of history clean from the stain of having believed this superstition. You see that nothing could be more false than this standpoint. In our text-books only that part of ancient astronomy is reproduced which coincides with the beginnings of our modern science. But in reality the ancient science of the stars was in the first place astrology, the doctrine of the influence of the heavenly bodies upon earth and mankind. By this reason it was highly estimated by the princes in Egypt, the nobles and the emperors in Rome, who certainly would have had not the least interest in an abstract astronomy in our sense of the word and would not have favoured and endowed it. The methods of computing the planetary motions, the conjunctions, the eclipses, *i.e.* astronomy in our sense, was only a technical implement for this higher aim. The epicycle theory, this admirable ancient theory of the planetary motions, was only a geometrical means for practical computations. It was not meant as an image of the world-construction; for nowhere in Ptolemy's "Almagest" do we find the dimensions of these orbits given. An often repeated sentence of a famous philosopher, Posidonius, says, that the physicist has to make out, upon physical principles, what are the real motions in the world, the astronomer does not care what body moves and what body is at rest, and every theory is acceptable to him that represents the phenomena. This sentence is wholly unintelligible, if we do not take into account that the astronomer wanted only the relative and apparent motions for his higher purpose, their influence upon the earth.

The judgment of astrology as a regrettable aberration is wrong in a double sense. We cannot regret a belief that has been the chief means of raising the science of astronomy to the height it reached already in those ancient times. And though it has been superseded by the later development of science and proved to be an erroneous theory, it cannot be judged for this reason an aberration of the human mind, just as some other erroneous theories, such as the vortex theory of Descartes, Newton's emission theory of light, the

phlogiston theory, or the theory of heat matter were not aberrations of the human mind. The way of science goes through error to truth, or more rightly, each former phase of science is error compared with later truth. Each cosmological theory in olden times was necessarily geocentric, considered the earth and mankind as centre and aim of the world. In this conception astrology was the expression of the belief that the universe was one unity, in which every part depended upon the others. If we place ourselves a moment into the ideas of those times then what more sublime aim could there be imagined than to investigate and to discover the most intimate connection between men and the world, between the course of the stars and happenings on the earth? And if we succeeded in discovering it, what science could have a greater practical importance for men?

From this standpoint we will not be astonished to find most of the great astronomers of antiquity also believing in astrology. The great astronomical work of Ptolemy, the "Almagest," is only a part of his whole treatise; the other part, the "Tetrabiblion," from which our citation was quoted, deals only with astrology, and it was in the next fourteen centuries studied with the same ardour as the "Almagest." The same holds for the astronomers of the middle age, the Arabian as well as the European, from Albattani until Regiomontanus; all of them while studying the science of antiquity occupied themselves with astrology. And all this time astronomy depended on astrology. It was the belief in the influence of the stars upon the earth and the hope to know the future that induced the Califs and the Sultans in the Orient to erect observatories, to pay astronomers and to have translated the ancient astronomical works. By this general interest in astrology the study of the difficult geometrical theories of the planetary motions was kept awake and even towards the end of the middle ages led to the perfection of trigonometrical methods. In Europe the Catholic church condemned astrology as opposed to its theology; she had adapted the world system of Aristotle to its doctrine and in this system astrology was not admitted. This did not prevent the learned monks and laymen from studying the works on astrology as well as other heathen literature, and to believe more or less in its truth. And at the dawn of the new age, astronomy received a fresh impetus, as a repetition on a

higher plane of its first history; the calendar was in disorder, so that fresh inquiries about sun and moon were necessary, and by the discovery of America and the Indies navigation of the oceans wanted the help of an astronomy of higher precision. And now astrology too once more rises up into a brilliant flame, before it is extinguished.

Probably social conditions strongly contributed to awaken in the 16th century an intense interest and belief in astrology. Out of the middle ages a new society, with new conditions and new antagonisms, arose. The discovery of new continents gave a fresh impulse to human energy and opened wide horizons of adventure; but the inflowing stream of gold raised all prices and improverished the mass of the peoples. While the human mind awakened from mediaeval sleep and enjoyed the new knowledge the desperate peasants rose into revolts that were crushed in streams of blood. The art and science of the Renaissance, the finest blossom of culture, grew up at the courts and in the homes of princes and rich citizens, while at the same time barbarous bands of mercenaries went ravaging and murdering through the lands of the highest civilization, such as Italy and Holland. The princes fought against the nobility, the nobility against the citizens, the peasants against the nobility and the princes, the citizens against one another,—a wild pell mell of dynastic, religious and civil wars, of which nobody could see the goal and outcome. Bewildered, men stood in the midst of this world of cruel struggle; and no less cruel was the world of fantasy that grew up in their mind. Never the belief in devils and witches rested so heavily upon their brains as in this time; on every side man felt himself surrounded and threatened by terrible powers. Certainly these same superstitions had been present in the middle ages; but then the powerful authority of the Catholic church had given comfort and certainty to the oppressed minds. Now, however, this authority was broken, and a new mode of thinking and feeling with the same security had not yet arisen. This state of mental derangement was a fertile soil for all kinds of belief and superstition.

It is no wonder that in such a time of transition the most highly cultivated minds turned to astrology. The fate of man apparently was subjected to cruel chance. But here was an outlook to a fixed

order. Here perhaps the torturing uncertainty about the future could be destroyed by linking the wavering destiny of men to the calculable course of the eternal stars.

You all know that modern astronomy was founded upon the long series of observations by Tycho Brahe. And what was it that induced him to make these observations? It was his belief in astrology.

Tycho Brahe, a Danish nobleman, belonged to that group of searching minds, so numerous in the 16th century, who, driven by a keen desire of understanding the secrets of the world, occupied themselves with every kind of science, with alchemy, with anatomy and with astronomy. We have a document in which he revealed his ideas on these matters, a public lecture given by him in 1574 at the University of Copenhagen, now reprinted in the edition of Tycho's complete works. Its title is significant already; "De Disciplinis Mathematicis,"—On the Mathematical Sciences—and it is almost entirely devoted to astrology. Astrology was for him just as generally at that time, the real mathematical science, the chief science for which mathematical methods were used. In order to show you, in addition to the Babylonian and the ancient aspect of this doctrine, also its 16th century character, I may cite some parts of it:*

"Whoever denies the forces and the influence of the stars undervalues firstly the divine wisdom and providence and contradicts moreover the most evident practice. For what could be thought more foolish about God than that He should have created this large and wonderful scenery of the skies and so many brilliant stars to no use or purpose—while even man makes his least work always with some aim. That we may measure our years and months and days by the sky as by a perpetual and indefatigable clock does not sufficiently explain the use and purpose of the celestial machine; for this

*In *Popular Astronomy* of June-July, 1929, a translation is given of the first part of this lecture by R. H. Coon; the translator says about it "While not possessing scientific value it has a genuine interest as it expresses the reflections of so distinguished a scientist." It is clear, however, that the omission of the second part of the lecture, treating on astrology, must give an entirely wrong impression of the real mode of thinking and of the reflections of Tycho. If there is any interest for us to get a right conception of the personality of Tycho a translation of the remainder of that lecture would be very desirable.

measuring of time depends only on the big lights, sun and moon and on the daily rotation. For what purpose, then, serve these five remaining, in different orbits revolving planets? . . . . . May we suppose that God has made such a wonderful work for no aim and use? . . . If thus the celestial bodies are placed by God in such way as they stand in their signs, they must have of necessity a meaning, especially for mankind, for whom everything chiefly has been created . . . . But not less those, who speak in such a way, violate clear evidence which it does not suit for educated people with sane senses to contradict. Who did not perceive that the difference in quality between the four seasons proceeds from the rising and the decreasing of the sun and its course through the twelve parts of the zodiac? We see too, that with the waxing of the moon everything cognate to her nature—such as the brains in the living beings, the marrow in the bones and the trees, the flesh in the shells and many things more—increases also, while it diminishes when the moon wanes. In the same way the flux and reflux of the wide ocean is affixed as with a chain to the moon's motion, so that immediately with the rising of the moon the sea also begins to rise. . . . . These and kindred phenomena are known even to uneducated people. Then sailors and peasants by repeated observation have perceived that from the yearly appearance and disappearance of certain stars they can predict occasional storms. The scholars, however, who are trained in abstract science have deduced that the configurations of the planets with one another or with sun, moon and stars have an influence too. They have observed that the condition of the air in the seasons of different years are changed by them in a different way. So it has been perceived that conjunctions of Mars and Venus in certain parts of the sky raise showers and sometimes thunderstorms. . . . . That important conjunctions of the big planets cause large changes in these lower parts of the world has been shown often by experience. So in 1563, when a conjunction of Jupiter and Saturn took place in the first part of the Lion, near to the nebulous stars of the Cancer, which Ptolemy calls the smoky and pestilent ones, did not then the heavy pestilence which made perish in Europe numerous people, show the influence of the stars by an undeniable fact?"

Then, after treating the opinions of those opposed to astrology, Tycho proceeds:

"But we, on the other hand, hold that the sky not only operates on the atmosphere but also directly upon man himself. Because man is made out of the elements he is subjected to the same laws as the matter of which he consists. Since, furthermore, the air which we inhale and by which we are fed not less than by food and drink, in different ways is affected by the sky, as has been shown above, it is unavoidable that we also are affected by it in different ways. And then I leave apart, what must be clear for every mind, that man by some hidden cause lives and is fed by the sky in a still higher

degree than by air, water and other low elements, and acquires an incredible affinity to the related stars; so that not wrongly ancient philosophers, among them after Pliny's testimony also Hipparchus, have said that our spirit is a part of heaven itself."

All this may not be very convincing to us because, for the real facts of experience as the yearly variations and the tides, we have other explanations founded upon the wider and more developed science, but it shows how strongly rooted in its author was the conviction of the truth of astrology. He was also practically engaged in it; when a prince or princess of Denmark was born, he calculated for the king's use their horoscopes after the common rules. But he was not all too confident in them himself; he often points out the uncertainty of the predictions, because he was convinced that the science of the connection between heavenly and earthly happenings was still in its imperfect beginnings. It was his aim to advance it and to discover the real details of these connections. The condition necessary to it was an exact knowledge of the events in the heavens, the motions of the planets. He had observed that the time of conjunction just mentioned, between Jupiter and Saturn, was given many days in error by the then existing planetary tables. Obviously they were not exactly right and the reason was that the elements, the numerical data of the circular movements, from which the tables had been computed, rested themselves only on a few observations, especially made for the purpose of ascertaining either the period, or the inclination, or the eccentricity of the orbit. Tycho was the first to realise that to find the real motions of the planets it was necessary to observe them continuously, one year after another as often as possible, so he resolved to devote his life to this task. From the king he obtained the small island Hveen as a feudal tenure, and the means of building an observatory and constructing instruments of the highest precision possible. With these he made during 16 years, 1580 to 1596, an extensive series of observations of the sun, the moon, the stars, the planets, the comets, with an accuracy hitherto unknown and only once again reached with instruments without telescope. After his departture to Bohemia, in 1596, the observations were still pursued, until his death in 1600. Then the discussion and computation of the orbits of the planets from

these observations was the task of his assistant, Kepler. The further history is generally known; how Kepler first attacked the problem of Mars, how he started from the same hypothesis as was always used till then, of eccentric circular orbits for the planets, and only substituted his sector law instead of the older explanations of the variable velocities. But there still remained some small differences between Tycho's observation and the computation from these orbits, so small indeed that formerly they would have been entirely disregarded, only 8 minutes of arc, but regularly recurring and too large for the high accuracy of Tycho's work. After years of troubles and trials he found at last the explanation that the orbits were not circles but ellipses. And so were found the laws of the planetary motions, the stepping stone for the rapid progress of astronomy in the next century, leading to the discovery of the laws of gravitation by Newton.

Thus we see that twice in the history of science up to the beginning of the 17th century there have been collected large series of observations of the planets; once in Babylon from the 8th century B.C. onward, and the second time in the 16th century by Tycho Brahe. And in both cases they supplied the foundation for a great progress of science, first the discovery of the planetary periods and the system of epicycles, building up the construction of ancient astronomy; the second the discovery of Kepler's laws and Newton's gravitation, the basis of modern astronomy. And both times it was the belief in astrology that gave the observers the patience and the high-minded endurance to pursue their work consistently through all these years and centuries.

After it had rendered this supreme service to science astrology went down. With the acceptance of the new world system of Copernicus, its basis,—the anthropocentric conception of the world, —was taken away. And at the same time in the 17th century political and social conditions settled into a new fixed order and so the mystical needs, that gave her strength in the former century, disappeared. Some of its doctrines were still fostered in this century; Kepler with his rich fantasy seems not to have given it up entirely; in the narrative of an English clergyman, Horrocks, on the first observation of a transit of Venus across the sun, he men-

tions the rainy weather caused by a conjunction of planets; and in the popular belief of the moon's influence on the weather we see still in our time its remnants. In the 17th century the princes still had their astrologers at their courts, but they were already partly considered as impostors. Astrology did not at once disappear, but its practice and theory are now only possible as a superstition, outside of science and beneath it. The astronomers now see new and other larger aims before them. The principle of which it once was the expression, the conception of the unity of the whole world, had now to take a new form; to find not the connection of universe and man—for man is now only a small and accidental attribute to one small planet—but to find the laws of the universe itself. On this new path astronomy has gone upward during the following centuries.

PRACTICAL ASTRONOMY FOR AMATEURS*

HOW THE AMATEUR ASTRONOMER IS HELPING TO OBSERVE AND CALCULATE THE MOON'S MOTIONS

By Ernest W. Brown

The chief difference between the amateur and a professional astronomer is often one of occupation only, and not one of expert knowledge. The professional astronomer makes that subject the main object of his work and the amateur the main object of his leisure. Hence there is nothing surprising in the fact of co-operation between the two groups, for the purpose of advancing our knowledge of the heavens. The main difficulty is to find lines of investigation which can be followed usefully when the hours of leisure are occasional. Three of these lines are the observation, the reduction, and the prediction of occultations of stars by the moon.

An occultation is the disappearance of the light of a star covered by the moon between the observer and the star. The observation of an occultation is a record of the instant of time when the limb of the moon blocks out the light of the star, or of the later instant when the star reappears from behind the opposite limb. From two such observations made near to one another the position of the centre of the moon at any instant near the times of observations can be calculated.

From the point of view of the observing astronomer this is one of the simplest of all observations which can be made on objects in the sky. If he has a telescope of sufficient power to see the star well—and the small instruments used by most amateurs are quite sufficient for the brighter stars—his observation is independent of

*This article, with some slight changes, by our recognized authority on the motion of the moon, is reprinted, with permission, from *Scientific American* for November, 1929. An effort is being made to secure in Canada observations of the sort described by Professor Brown. At the present time astronomers of the Ottawa and Victoria observatories and the University of Toronto are conferring as to the best way to undertake this work. The necessary calculations and predictions will be printed in this Journal.—*Editor.*

any defects of his telescope. Even with the largest instruments the star disappears within a small fraction of a second when the sky is clear of clouds and haze.

The first question which will naturally be asked is the accuracy with which the instant of disappearance or reappearance must be recorded. The answer is that for the chief needs of the subject at present it is sufficient if the event is obtained to the nearest second of time. Thus, as far as the personality of the observer is concerned, it is only necessary to be able to record an event which is seen by the eye, while with the ear the beats of the pendulum of a clock are being counted. A little practice—which can nowadays be obtained by trying to record the changes of the traffic lights in the streets—will soon give the observer the needed facility. Of course, if he possesses a stop-watch, the observation is evidently much easier, because it is not necessary to do any counting of seconds.*

The final need is some means of obtaining the time accurately. In these days of wireless time signals sent out at least twice a day, all the observer requires is a chronometer or clock which will hold its rate accurately for some 12 hours. Even this can be dispensed with if the observer can get into telephonic communication with some nearby observatory within a short time of making the observation. It is necessary that the observer should know his geographical longitude and latitude within two or three seconds of arc, but this is obtained once for all without much difficulty, by referring his position to some spot within a few miles which has been accurately located by the Coast and Geodetic Survey.

The calculation of the position of the moon from the observation is ordinarily one for the mathematical astronomer. This process is called the "reduction" of the occultation. It has been simplified to a set of rules which can be followed by anyone who knows a little elementary trigonometry and understands how to use tables of logarithms. A good computer who has learned the rules can perform a reduction and check the work in about an hour. A beginner will naturally take longer, but practice soon gives rapidity and ease in performing the calculations.

A considerable number of amateur astronomers in America,

*Full instructions are given in *Popular Astronomy*, vol. 35, p. 17 (1927).

England and other countries have undertaken this work of observing and reducing occultations. Some observe, others who have not the necessary opportunities to observe, reduce, and still others observe and reduce occultations. Some three years ago the American Association of Variable Star Observers—the "A.A.V.S.O," as it is now everywhere known in astronomical circles—began to extend its activities beyond those which its name implies, and under the enthusiastic leadership of Mr. J. E. G. Yalden, of Leonia, New Jersey, formed a committee which has now grown into a section, to deal with the occultations. The first task of the committee was to secure members who were able and willing to reduce occultations. Many astronomers, professional and amateurs, publish observations from time to time: a few of them make observations available for discussion by reducing them, and it is this work which was and is most needed.

At the same time, the British Astronomical Association, which under its abbreviated title, the "B.A.A.," is a society in which amateur and professional astronomers co-operate in various ways for the advancement of astronomical science, formed a section to deal with occultations. Dr. L. J. Comrie, who some years ago was working in the United States and is now assistant superintendent of the British Nautical Almanac Office, gathered together a number of members of the B.A.A. and started them on the work of predicting occultations.

Ordinarily, the times when occultations of bright stars will occur are predicted only for the national observatories. These predictions are necessary so that the observer may know when to go to his instrument. The predictions are furnished with an accuracy of a minute or two, so that the observer need not waste a lot of time waiting for the event to occur. The British Committee is now covering nearly the whole of Europe and some regions in other countries with annual predictions. Elsewhere, and particularly in the United States, observers had in general to make their own predictions, but this matter is now being taken up more systematically.

By a method devised by Dr. Comrie a single set of predictions can be made to serve for an area some 600 miles in diameter, so that a few such sets will cover a large field. Within the last year, the B.A.A. has added the work of the reduction of occultations to its

programme, this being taken care of by its computing section under the chairmanship of Mr. McNeile. For convenience and to avoid duplication, the B.A.A. takes care of all unreduced occultations observed within the British Empire, while the A.A.V.S.O. looks after the remainder.

There are others who are not directly affiliated either with the A.A.V.S.O. or the B.A.A. who are adding to the story. One of these, Dr. J. Moir of Johannesburg, South Africa, furnished a long list of observations in 1928 which was received a few months ago. His recent death is a distinct loss. His contributions were stimulated by the emeritus director of the Union Observatory in that city, Dr. R. T. A. Innes, who was in one sense the source of the present campaign, since it was he who in 1923 started the observation and reduction of occultations on a large scale.

CHANGES SINCE 1650

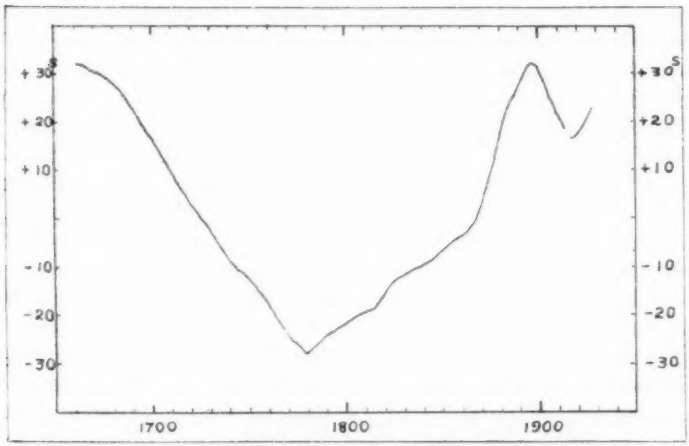

Figure 1: Irregularities in the earth's rotation derived from the moon's motion.

Then there are several teaching observatories which have made the observation and reduction of occultations a part of the work which is assigned to students. In this way the student not only

learns several important parts of his subject, but has the satisfaction of feeling that the work he does is a permanent contribution to the science.

How the work has grown may be judged from the fact that in the first year of the campaign, which dealt with the observations made in 1926, 160 reduced immersions were available for discussion, 62 of which were calculated by members of the A.A.V.S.O., by students and by others who volunteered to help. In 1927 the list had grown to 418 and it contained nearly every observation published or communicated by letter which could be utilized. Over 600 completed results have already been received for the year 1928, and there seems to be little doubt that the number for 1929 will equal or surpass that for 1928. Additional offers of help from volunteers are being continually received and there is now much less difficulty in taking care of the observations than was experienced last year.*

A new and valuable addition to the campaign is the formation of an occultation section of the Bond Astronomical Club in Cambridge, Massachusetts. At present this section is engaged in collecting and reducing the observations which were made in 1924, a year in which the reduced occultations were fewer in number than was needed to make a good determination of the mean for the year. When the club has completed this work, our knowledge of the apparent position of the moon at any time since the beginning of 1923 will far surpass in accuracy that of any previous year.

Since this article is mainly concerned with the help which the non-professional astronomer is giving to finding the apparent motion of the moon, no mention has been made of another class of observation which is made a regular part of the programme at the national observatories of Greenwich and Washington. At these places the observer notes the exact instant at which the moon crosses the meridian, that is, the instant when it is exactly south of the observer. On account of the difficulty of observing the moon when it is close to the sun, and the frequent cloudy nights, only about 100 such observations are obtained at each place in a year. Greenwich has kept the record regularly for 180 years and that observatory gives us our chief source of information for the motion

*The results are published from year to year in the *Astronomical Journal*.

of the moon during the past two centuries. In the final discussion of the motion at the present time these observations are included, and by comparing the results with those deduced from occultations we expect to learn more about the errors by which all such observations may be affected.

Articles in previous issues of the *Scientific American* have described the main object of this work, which is now the determination of the rates of length of the day. What we get from the observations is the apparent position of the moon, on the assumption that the length of the day is constant. This assumption means that the rate at which the earth turns on its axis does not change. Now we know from the law of gravitation just how the moon ought to move in the sky, and it has been shown with a considerable degree of

THE LAST 53 YEARS

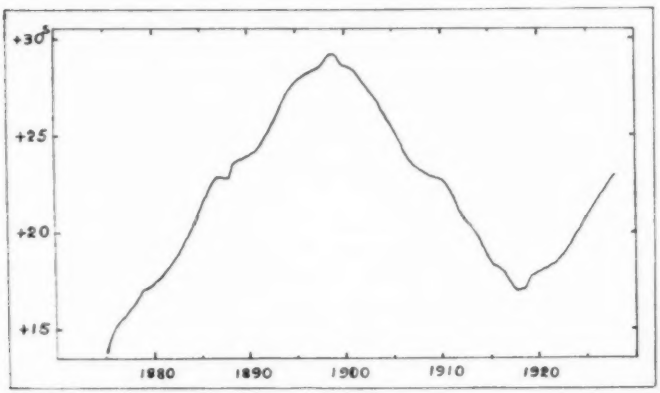

Figure 2: In 1928 the earth was 25 seconds ahead of its average rotational motion during the last three centuries.

probability that the difference between its theoretical rate and its observed rate is due to changes in the rate of rotation of the earth.

During the last 300 years these changes have been oscillating. The curve (Figure 1) seems to show a period of some 250 to 300 years. But this period is quite rough. There are minor fluctua-

tions of very considerable extent, which cannot be predicted. A feature of the curve is the sudden changes which appear to be characteristic. Figure 2, which gives the curve for the last 53 years on a larger scale, shows one about 1898 and another near 1917. If one might judge from the past another such change is due within the next ten years. But predictions of these changes have had a bad habit of coming to grief and this one is mentioned with great hesitation, and only because it adds to the interest of the work to look for an expected event, even if the expectation may be disappointed. At the present time, the earth is rotating a little faster than the average and the rate seems to be increasing. If we may judge the future from the past—and there seems to be no other guide at present—this rate should begin to decrease within a few years and should continue to do so until the earth is rotating more slowly than the average.

The total changes known with any certainty in the past are very small; the greatest known is one in which the apparent loss or gain of time was about one second in a whole year. This is only about one part in 30,000,000. Small as this amount is, we can now detect much smaller changes. With the new material derived from the occultations there should be no difficulty in detecting changes from year to year of one part in 300,000,000 in the average length of the day.

RADIO TALKS ON ASTRONOMY OVER CFCT

By W. E. Harper

XXIII. The Earth's Atmosphere

(January 8, 1930)

I have taken a very simple topic for my ten-minute chat with my radio audience this evening. The air we breathe used to be considered a chemical element but in the 17th and 18th centuries it was discovered to be simply a mixture, chiefly of two gases. These are oxygen and nitrogen in the proportions roughly of 21 per cent. oxygen to 79 per cent. nitrogen. Then we have other constituents, such as water vapour, in varying amounts, carbon dioxide, ozone, traces of nitric acid and ammonia as well as small amounts of the inert gases like argon and neon.

Several hundred tests by various investigators, among whom may be mentioned the great Cavendish, have shown that there are minute variations of the percentage composition of each of these constituents. Thus the air in parks and open spaces always contains a measurably higher percentage of oxygen than air in crowded districts. Carbon dioxide is likewise more noticeable in city than in country air and is greater, too, in air over land than over the sea. But, speaking broadly, the various agencies that tend to modify the constitution of the air nearly neutralize each other so as to leave the composition practically unaltered. It may be added that the amount of ozone varies with the seasons, being a maximum in the early spring and falling off gradually until a minimum is reached in the winter time.

We have evidence of the presence of these substances in our atmosphere in other ways than by merely taking a sample of air and analysing it. When we pass sunlight through our analyzing spectroscope and sort the colours out side by side, we see hosts of lines whose positions coincide with those of well-known elements analyzed in our laboratories. Thus in the solar spectrum occur lines corresponding to water vapour, to mention only one of the constituents. We know that these originate not in the sun but in

the earth's atmosphere. For one reason, the water vapour lines are weakest at noonday and strongest when the sun is on the horizon as should be the case, since in the latter position the rays are coming through the greatest length of water-laden atmosphere. Moreover, as the sun is rotating about an axis one limb is approaching the earth while the other is receding from it. This causes the true solar lines to oscillate back and forth in the spectrum and as the lines in question are stationary and do not share in these oscillations they must have their origin in our own atmosphere.

Then, too, impurities get into our atmosphere through the action of volcanoes on the earth. This fine dust is blown up into the upper atmosphere and carried by the air currents as invisible clouds for years before it eventually settles to the earth again. The most notable instance of this was the eruption of Krakatoa, a volcano on an island near Java, which on the 27th day of August, 1883, blew up a portion of the island, leaving perpendicular walls 1,400 feet high. The explosion was heard a few thousand miles away, while the resulting tidal wave stranded all shipping in nearby harbours and resulted in the loss of about 36,000 lives. What concerns us more in connection with our topic is the fact that huge quantities of fine dust were projected at least 17 miles into the upper atmosphere where the prevailing air currents carried it around the earth in an east and west direction. Later it diffused itself over the whole earth and lessened, as measurements showed, the amount of radiation reaching us from the sun. Highly coloured sunsets were the rule for several years.

And by the way, we have thousands of somewhat similar volcanoes belching out their stream of dust particles day by day. We have a few even in Victoria as evidenced by the pall of smoke from factories and sawmills that the prevailing southwest winds carry over a portion of the city. Within the past few years machines which automatically register the pollution of the atmosphere and show the enormous quantities of dirt that people are compelled to breathe have been used in investigations of this type. Such research has focussed public attention upon this evil and in many places the nuisance has been greatly lessened if not indeed wiped out altogether. Somewhere recently I read that either Pittsburg or Philadelphia—I think it was the former, a city long known as

the Smoky City—had so overcome the evil that it was now one of the cleanest of cities. Health should always take precedence over material wealth.

Our earliest impressions were that the atmosphere extended up a few miles—later increased to 30 or 40—with the temperature gradually becoming lower as we went up. Evidence to this effect was seen in the snow which covered the nearby hills whilst melting or falling as rain in the valleys. It was emphasized by the perpetual snow-capped peaks of our highest ranges, a feature which makes the majestic Olympics across the straits such an imposing picture in summer for Victorians. Continuous records over many years at stations of various altitudes from sea level up to one of four miles in Peru have shown us that our early ideas of temperature decreasing with increasing altitude were correct. But with the introduction in this century of self-recording apparatus which is carried aloft by kites and balloons much new information has come to us of the state of the atmosphere above the four-mile limit previously studied. These sounding balloons of fine rubber, usually a few feet in diameter, carry automatic recording thermometers and other equipment and are carried to great heights before the balloon bursts, allowing the equipment to fall to earth protected by a parachute. A tag is always attached offering a reward for the return of the instrument. A recent press despatch states that one sent up in the Middle States travelled over 400 miles before landing on an Ontario farm, near where the speaker was born. By means of these sounding balloons we know considerable about the temperature and density of the air up to a height of twelve miles. Let me give you the results for the summer temperatures. At sea-level we have a temperature of approximately 15°C., two miles up it is zero or just freezing, four miles up it is −20°, while at seven miles up it has fallen to −50°. From this point upwards no lowering of temperature occurs; it appears to be practically at a constant temperature as if the atmosphere just absorbed as much heat from the sun's rays as it radiated onwards to the earth. This isothermal region, where the temperature is constant and approximately 50 to 60 degrees below zero Centigrade, continues up as high as our balloons have yet reached, namely, 24 miles.

Higher up than this our information is limited to such deduc-

tions as properly may be drawn from various phenomena. The twilight arch, roughly 42 miles high; the paths of shooting stars, rarely ever seen as high as 125 miles; the aurora from 50 to 400 miles high, all contribute in some measure to our knowledge of the physical condition of the air at the very high levels. We may say, then, that up to 20 miles it is comparatively well known, but beyond that level only deductions, growing less certain with increase of elevation, can possibly take us for the present.

XXIV. The Selective Character of Our Atmosphere (February 12, 1930)

In my last radio talk I told you something about the composition of the air we breathe, its extent and the temperature at different heights above the earth's surface. The picture I tried to leave with you was of a great blanket-like covering hugging the earth, being densest at the earth's surface and gradually thinning out with increase of height until it became extremely rarefied at heights of 150 to 200 miles.

As we move about in the air freely we sometimes fail to realize that it has any mass. Nevertheless its mass is considerable as a column of air extending from sea level up to the upper limit mentioned weighs as much as a similar column of mercury 30 inches high. In high mountainous regions we are above the densest part and experience a sense of the load being partially lifted from us.

This thinning out produces changes in the appearance of the heavenly bodies, depending upon their position in the sky. When the sun is low down in the sky its rays are passing through scores of miles of dense air close to the earth's surface and the shorter blue and violet rays find it exceedingly difficult to get through. Consequently the sun appears much redder at sunrise and sunset than when it rides high in the heavens at noonday. This phenomenon is much more accentuated if the sky be filled with dust or smoke. Similar phenomena are witnessed at night in the case of the moon, the planets and the stars. All appear more reddish near the horizon, and as the astronomer is seeking to obtain the maximum amount of blue light to which his photographic plate is sensitive he pays attention to the object when it is highest up in the sky. Other

things being equal, too, the more elevated the site of an observatory is, the better for photographic work.

But even the purest air is not altogether transparent to light and it is estimated that when conditions are best with the sun directly in the zenith less than 70 per cent. of the sun's radiations get through this blanket of atmosphere. The remainder is mostly reflected back into space but a small proportion is scattered from very fine dust particles suspended in the air or even from the molecules of air. This scattering is very pronounced in the case of the short blue and violet wave-lengths and as a result we have the blue of the sky. I repeat that the light from the sky is merely sunlight scattered by very fine particles or air molecules, which scattering is very pronounced for the blue.

Some years ago it was discovered that the sun was varying in its output of total energy and to some extent in its light. In this it is no different to thousands of other stars. These fluctuations occur over a few days or weeks or again over long periods of time. The variations are of the order of five or six per cent., and while not large were considered sufficiently so to be effective in causing climatic changes upon the earth. It has not been as easy as expected to work out the connection between the two and the principal drawback it would appear has been our lack of knowledge of what goes on in our own atmosphere. In particular the manner in which the ultra-violet radiation is affected presents a problem, but some advance has been made.

It has long been known that the number of sun spots on the sun's surface varies over an 11½-year cycle. We passed through a maximum in 1928 and are now approaching a minimum. Measurements of the amount of ultra-violet light reaching us from the sun during the past half-dozen years have shown that there is a marked parallelism between such amount and the solar activity as represented by the sun spot cycle. Years of maximum solar activity are marked by great outpourings of ultra-violet light from the sun and *vice versa*, the variations being as much as fifty per cent. These ultra-violet radiations are the ones above all others that are most effective in producing changes upon the earth and thus it is desirable to learn all we can about them.

In the spectrum, instead of speaking of the red region and the

blue region, we assign numbers which are the exact wave-lengths representing the colours. On the usual scale, the centre of the red region is approximately 6700, whilst that of the blue region is, say, 4700, and the violet perhaps 3900. The ultra-violet extends from about 3700 to the shorter wave-lengths, but in the case of sunlight our atmosphere acts as a trap, refusing to allow radiations of wave-length shorter than 2960 to get through.

What is it that acts as the barrier? It is found that it is the presence of a layer of ozone in the upper air which, while very thin, has a marked effect on the radiation. Not only does it absolutely refuse to transmit radiations shorter than 2960 but it deals differently at different times with those radiations just bordering on the limit. The amount that it lets through varies from hour to hour of the day because the sun's rays must traverse a greater thickness of the layer at sunset than at noonday. This discrepancy will be greater the closer the surrounding ozone layer is to the earth, as may be verified by a simple diagram, and by a process of trial and error it is possible to assign an altitude that will best agree with the amounts absorbed in this region of the solar spectrum. Thus by taking spectra of the sun from hour to hour throughout the day with equipment suitable for this ultra-violet region we can deduce from the absorption shown the thickness and the height of the ozone layer. Such studies have been carried on in Southern France, in Switzerland, in England, at Mt. Wilson in California, and at Toronto. It is found that there is good agreement as to its height, the value given being 25 miles. At this altitude the pressure would not be above 1/1000th of that at the earth's surface. The amount necessary to do the trick is surprisingly small for if it were at atmospheric pressure one-eighth of an inch in thickness would provide the necessary absorbing power.

In all the places where the ozone layer has been studied, it is found that there is a marked variation from month to month throughout the year. The thickness of the layer is greatest in the beginning of spring and decreases during the summer months to a minimum in the winter time. Probably, as the summer heat increases, the ozone begins to decompose faster than it is formed, as heat has been found detrimental to its existence.

The amount of the ultra-violet that gets through from the sun

seems to vary from place to place, a maximum having been found in Egypt. Too little work, however, has been done upon this question and it is highly desirable that our own country should make more investigations along this line. If there are marked differences from place to place such knowledge would be exceedingly valuable in selecting sites for tubercular hospitals and solaria.

The presence of ozone in the upper air calls for some explanation as it is heavier than ordinary oxygen. The ordinary oxygen molecule has two atoms; ozone has three. It can be formed in the laboratory by passing an electric discharge, or ultra-violet light from any source, through oxygen. Thus in the upper air where the ultra-violet radiation from the sun falls on ordinary oxygen it breaks up the molecule into two parts of atomic and more active oxygen. These seek the company of molecular oxygen and ozone is the result.

It is fortunate for us that there is this layer of ozone screening off the greater part of the sun's ultra-violet light for it is injurious to our bodies and harmful to the life of plants. Under the guidance of a skilful physician limited exposures to ultra-violet radiations are beneficial but wholesale and long-continued doses of it would be our undoing. In an earlier talk I told you of our atmosphere acting as a cushion, absorbing the shock of the meteors that bombard us by thousands every day. Here we see another wise provision of Nature to screen us from the injurious solar radiations of short wave-length.

REVIEW OF PUBLICATIONS

The Spectral Distributions of Stars brighter than Mag. 7.0 in the Henry Draper Catalogue, by Otto Seydl. Publication C. 6 of the National Observatory of Czecho-Slovakia at Prague.

The distribution of stars of magnitude 7.0 and brighter of the H.D.C. is studied in their relation to the galactic system. The work follows very much the same lines as the more extensive statistical notes on the Draper Catalogue given by C. V. L. Charlier in the Publications of the Lund Observatory, Volume 4, part 3. The present publication, however, is more detailed in division according to magnitude for the brighter stars; and while the two works overlap, each has its value to workers in spectroscopy. The tabular matter which is contained in Part I is supplemented by a beautifully printed set of maps in Part II, which give a graphical representation of the density distribution of the stars for each type and magnitude in various parts of the sky.

R.K.Y.

Introduction to Physical Optics, by J. K. Robertson, Professor of Physics in Queen's University, Kingston, Ont. 422 pages, 5½ × 8½ in., 223 fig. N.Y., Van Nostrand, 1929, Price $4.00.

The unusual activity in scientific pursuits which has characterized the beginning of the twentieth century has been accompanied by much writing, not only in original articles appearing in journals of science, but also in books for the layman and the specialist and for the student and the teacher. This is quite as true in Physics as in other branches of science, because in that field many fundamental discoveries have been made in recent years. The result is that from the teacher's standpoint the text books in that subject of a few years ago lack the stimulus of our newer achievements, and many of those engaged in teaching in schools and colleges have felt for some time the need of books with a more modern viewpoint. The difficulty is, however, that new discoveries usually are the result of more advanced thought, the details of which are

not familiar to the undergraduate student, and hence the incorporation of such work in text books is not a simple matter from a pedagogical standpoint.

This new volume by Professor Robertson is an attempt to present an important subject in a more modern way. He has brought a teacher's thought and skill to the task of weaving together the best results of classical thought in Physical Optics with what appear to be the more clearly verified modern advances. It is impossible in reading the book to avoid harking back a century ago to the time of Young and Fresnel, who may be regarded as the founders of the subject of Physical Optics. I think it may safely be said that there is no branch of science out of which there has come such a variety of delicate and beautiful experiments to please the mind and stimulate the imagination as the study of the wave motion of light advocated with such skill and conviction by these two scientists. When one recalls the beautiful effects of the interference of light waves, whether in thin films or in crystalline media, in the colours of diffraction effects to be observed in gratings of various forms, or in coronas and halos in the sky, to say nothing of the hundred and one examples of nature's colours in the shells of the sea and the plumage of birds, one feels that Professor Robertson must have bent to his task with real enthusiasm. The book is itself an evidence of it.

It can be recommended to all students who have had the equivalent of a year's work in physics in the University, and have a good amateur's acquaintance with experiment. The chapters on the "Electro-magnetic Theory of Light" and on "The Origin of Spectra", give a clear presentation of the recent progress made in the study of the atom and its radiations. The last chapter deals with experiments on the speed of light and the interesting results leading up to the modern Theory of Relativity. The earlier chapters deal in a clear and readable manner with the fundamentals of the Wave Theory and the history of its developments.

The book is a well bound volume, with many diagrams and several very fine plates showing photographic reproductions of interference and diffraction effects, and some representative types of spectra.

H. A. McTaggart.

PLATE VI

TRANS-NEPTUNIAN PLANET

The faint dot at the tip of the arrow is the object discovered at the Lowell Observatory. (See page 193.)

Taken with the Metcalf 16-inch telescope at Harvard Observatory, 1930, Mar. 20.06 G.C.T. Enlargement 5x.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

A NEW MAJOR PLANET

The most interesting news in the astronomical world in recent years is the report sent out on March 12 from the Lowell Observatory that an object apparently fulfilling the necessary conditions for a planet beyond Neptune has been discovered.

On March 13, Director V. M. Slipher issued the following Observation Circular:

THE DISCOVERY OF A SOLAR SYSTEM BODY APPARENTLY TRANS-NEPTUNIAN

The message sent last night (March 12) to Harvard Observatory for distribution to astronomers read as follows:

> "Systematic search begun years ago supplementing Lowell's investigations for Trans-Neptunian planet has revealed object which since seven weeks has in rate of motion and path consistently conformed to Trans-Neptunian body at approximate distance he assigned. Fifteenth magnitude. Position March 12, 3h. G.M.T., was 7s west from Delta Geminorum, agreeing with Lowell's predicted longitude." (For ease in finding the object it was referred to Delta Geminorum. Position March 12.14 G.M.T., R.A., $7^h\ 15^m\ 50^s$, Dec. 22° 6′ 49″.)

The finding of this object was a direct result of the search program set going in 1905 by Dr. Lowell in connection with his theoretical work on the dynamical evidence of a planet beyond Neptune. (See L. O. Memoirs, Vol. 1, No. 1, "A Trans-Neptunian Planet," 1915). The earlier searching work, laborious and uncertain because of the less efficient instrumental means, could be resumed much more effectively early last year with the very efficient new Lawrence Lowell telescope specially designed for this particular problem. Some weeks ago, on plates he made with this instrument, Mr. C. W. Tombaugh, assistant on the staff, using the Blink Comparator, found a very exceptional object, which since has been studied carefully. It has been photographed regularly by Astronomer Lampland with the 42-inch reflector, and also observed visually by Astronomer E. C. Slipher and the writer with the large refractor.

The new object was first recorded on the search plates of January 21 (1930), 23rd, and 29th, and since February 19 it has been followed closely. Besides the numerous plates of it with the new photographic telescope, the

object has been recorded on more than a score of plates with the large reflector, by Lampland, who is measuring both series of plates for positions of the object. Its rate of motion he has measured from the available material at intervals between observations with results that appear to place the object outside Neptune's orbit at an indicated distance of about 40 to 43 astronomical units. During the period of more than 7 weeks the object has remained close to the ecliptic; the while it has passed from 12 days after opposition point to within about 20 days of its stationary point. Its rate of retrogression, March 10 to 11, was about 30″ per day. In its apparent path and in its rate of motion it conforms closely to the expected behaviour of a Trans-Neptunian body, at about Lowell's predicted distance. There has not been opportunity yet to complete measurements and accurate reductions of positions of the object requisite for use in the computation of the orbit, but it is realized that the orbital elements are much to be desired and this important work is in hand.

In brightness the object is only about 15th magnitude. Examination of it in the large refractor—but without very good seeing conditions—has not revealed certain indication of a planetary disk. Neither in brightness nor apparent size is the object comparable with Neptune. Preliminary attempts at comparative colour tests photographically with large reflector and visually with refractor indicate it does not have the blue colour of Neptune and Uranus, but hint rather that its colour is yellowish, more like the inner planets. Such indications as we have of the object suggest low albedo and high density. Thus far our knowledge of it is based largely upon its observed path and its determined rates of motion. These with its position and distance appear to fit only those of an object beyond Neptune, and one apparently fulfilling Lowell's theoretical findings.

While it is thus too early to say much about this remarkable object and much caution and concern are felt—because of the necessary interpretations involved—in announcing its discovery before its status is fully demonstrated; yet it has appeared a clear duty to science to make its existence known in time to permit other astronomers to observe it while in favourable position before it falls too low in the evening sky for effective observation.

Flagstaff, Arizona
March 13, 1930

The chief difference between the body actually observed and that predicted by Lowell seems to be in its size. He estimated its mass as about 1/50,000 that of the sun, its size between the earth and Neptune, and he expected that it would show a disc with a diameter greater than 1″ and would have a magnitude 12 or 13. For a final determination we may have to wait for observations in the future, or possibly photographs taken twenty or twenty-five years ago, showing the object, may be found.

The object is shown on the photograph reproduced in Plate VI. It was taken at Harvard Observatory with the Metcalf 16-in. telescope on March 20. The photograph was kindly supplied by Mr. P. M. Millman, who states that on the night of March 21 he was able to observe the planet with the 15-inch Clark telescope. It was just at the limit of visibility and was detected only after working for two hours in complete darkness.

Comets Discovered with a Small Telescope

Amateurs will be interested to learn that the instrument used by Dr. Wilk, of Cracow, Poland, when he discovered comet 1930*c* on March 21, was a Zeiss prism monocular telescope "Asem" of aperture 80 mm. (3 1/8 inches), power 40. The comet 1925XI, which bears the name Peltier-Wilks, was discovered by Wilk on November 19, 1925, with a 7-power field glass and confirmed with the "Asem" telescope.

Naked Eye Observation of the Satellites of Jupiter

From time to time in the "Notes and Queries" department of this JOURNAL have appeared notes concerning naked eye observations of the moons of Jupiter or of the phases of Venus. On Thursday, March 6, while in the Columbia University Observatory with one or two visitors who were being shown certain objects with the twelve-inch Clark refractor, an elderly gentleman, whose name I did not get, remarked to me that he could see the satellites of Jupiter at that moment without optical aid. He further offered to locate for me their apparent position, and asked me to check his observation with the telescope.

He used the "clock-face method," and stated immediately that to his eye there appeared to be two moons at about five o'clock and one other at about eleven o'clock. In the telescope, equipped with an inverting eyepiece, there were three satellites at eleven o'clock (one quite close to the planet) and one at five o'clock, thus verifying his observation exactly. The third of the satellites visible in the telescope at eleven o'clock, being so close to the planet, was probably invisible to him.

He then went on to say that seeing these objects was quite the usual thing with him, and that he thought it not particularly difficult.—JAMES H. LOGAN, 327 Hartley Hall, Columbia University, New York City. C.A.C.

NEWS AND COMMENTS

The Ottawa Centre of the Royal Astronomical Society of Canada will hold an At Home at the Dominion Observatory on May 2, when members and their friends will have an opportunity of inspecting the various divisions of the work of the observatory.

In the past the Dominion Observatory has been open to visitors on clear Saturday evenings for observing with the fifteen-inch equatorial. Commencing on April 12 the observatory is to be open to the public every Saturday evening. If the sky be too cloudy for viewing the heavens a selection of astronomical lantern slides will be shown with a short accompanying talk. Also, one of the seven divisions of the observatory will be open for inspection and the work explained each Saturay evening.

A despatch from Moscow, which possesses a Zeiss planetarium, announces that this excellent equipment for popularizing astronomy will be installed also in Leningrad, Kharkoff, Sverdlovsk, Novosibirsk, Frunze, and Tiflis.

Mr. W. H. Connell, late of the Survey of India, now with Cooke, Troughton and Simms, recently paid a visit to the Dominion Observatory and the Surveys branches in Ottawa, looking up specially the old Cooke and Troughton and Simms instruments in use there. He reports some important new developments in portable equatorial telescopes using light alloys and stainless steel, *e.g.*, a five-inch telescope of 18 lbs., and with clockwork and counterweight, 53 lbs.

Professor Wilk of Cracow Observatory discovered a comet of the seventh magnitude in Pisces, on March 21.

Dr. T. J. J. See, who, as a captain in the U.S. Navy, has been in charge of the naval chronometer and time station at Mare Island, California, for the past twenty-seven years, has retired from active service, having reached the statutory age of sixty-four years.—(*Science*).

Dr. V. M. Slipher, Director of the Lowell Observatory at Flag-

staff, Arizona, fittingly announced the discovery of the ninth planet, on March 13, the anniversary of the birthday of the founder of the observatory, Dr. Percival Lowell. The search for the planet indicated by Lowell's mathematical work published in 1915, has been carried out by photography. The image of the planet was first discovered by Mr. C. M. Tombaugh, on January 21, on a plate made by the special Lawrence-Lowell telescope. It has since then been observed photographically with the Lowell reflector by C. O. Lampland, and observed visually with the large refractor by all the members of the staff. The observations seem to indicate that it is the object found mathematically by Lowell. Heartiest congratulations are extended to the staff of the Lowell Observatory on this fine achievement.

Mr. E. A. Hodgson left the Dominion Observatory on April 10 to attend the meetings at Vancouver, on April 16 and 17, of the committee which is arranging the preliminaries for the Pan-Pacific Science Conference to be held in Canada in 1932. Mr. Hodgson is chairman of the Committee on Seismology and Volcanology. On his return he will go to Washington, D.C., to attend the meetings of the Seismological Society on May 1 and 2.

The path of the total phase of the solar eclipse of April 28, 1928, has been recomputed at the U.S. Nautical Almanac Office, Washington, D.C., under the direction of Professor James Robertson, using observations of occultations observed at the Naval Observatory up to March 12. A correction of +5.47 seconds was obtained to the Moon's mean longitude.

Under the Dome

Stranger—"Does Mr. Jones work in this building?"

Astronomer—"No one of that name is on the staff of the observatory."

Stranger—"I was told to enquire at the building with the tank over it."—(C.C.S.)

REDEL.

MEETINGS OF THE SOCIETY

At Ottawa

February 28.—An open meeting was held in the Victoria Memorial Museum. The President, Mr. C. C. Smith, was in the chair.

Mr. Smith introduced the lecturer, Dr. R. K. Young of the Department of Astronomy, University of Toronto. The title of the lecture was "Interesting Objects in the Sky," and the speaker dealt with the subject in a most pleasing manner, making it readily understandable to even the youngest member of the audience.

Dr. Young spoke of the valuable wotk that could be and is being done by amateurs, suggesting that the most profitable fields open to them are in the observation of meteors and of occultations.

Although the sky is replete with interesting objects, a knowledge of them is requisite in order that they be fully appreciated. Few celestial objects are spectacular, yet these very objects are extremely fascinating to one who has made even a brief study of them.

Before the invention of the telescope, there was great speculation as to the place the earth, sun, moon and planets occupied in the scheme of creation, and men had almost satisfied themselves that the earth was spherical and that the Copernican theory of the solar system was a fact. When, however, Galileo looked through the first telescope and saw the moons of Jupiter, the crescent of Venus and other phenomena, the scientific world was thrilled by these discoveries which added so much weight to the Copernican theory. The long study of the problem beforehand heightened the interest. Jupiter, Venus and the planets in general are not brilliant, but the simple facts of observation imply so much, that, coupled with understanding, they become fascinating in the extreme.

To really appreciate a view through a telescope one should read about the object beforehand, and then the pleasure of the actual observation will be much increased. Quite likely the observer will not see all that he expects, but this may encourage him to re-read and to re-observe and so come gradually to master all that has been found out about any object and the way it has been found out. Progress in science, and in astronomy in particular, consists in study, observation,—study, observation, and so on over and over again.

Each of the planets in the solar system is interesting and the sun itself is a wonderful object for study. All the stars are fascinating from the very fact that we can find out so little about each. They whet our curiosity. However, let any amateur look at any bright star, find out its name and then satisfy himself or herself that he or she has read everything that has been published or known about that object, and the said amateur will look at it with awe, even if it appears in the telescope as a mere point of light. Some stars are interesting from their great distance, others again from the conditions existing within them. There are stars, thousands of times less dense than air, but so intensely hot that the

temperature at their centres must be millions of degrees. There are other stars so dense that a cubic foot of the material would represent over 2,000 tons.

By observation, by study and by deduction, astronomers are finding out interesting facts every year, almost every day. A certain scientist one time exclaimed that so much was known that there was nothing else to investigate and regretted that he had not been born sooner. That was over 50 years ago. The increase in knowledge (scientific) in the last fifty years has probably far exceeded all previously known. What will the knowledge of the world be a century hence or a thousand years hence? If one were choosing the time of one's existence on the earth, the year 3000 A.D. would probably be far more interesting than a date a thousand years in the other direction.

Throughout the lecture Dr. Young showed some most fascinating and beautiful slides of many celestial objects. Of special interest were those of the dark nebulae and also ones showing the resolution into stars of the great spiral nebula in Andromeda, this, by the 100-inch telescope at the Mount Wilson Observatory. Many other slides were shown and carefully explained.

At the close of the lecture, Mr. Smith expressed to Dr. Young the appreciation of the Ottawa Centre for his splendid address.

March 28.—The last regular meeting of the season was held in the Victoria Memorial Museum. The chair was occupied by the President, Mr. C. C. Smith, and Dr. R. E. DeLury, Assistant Director, Dominion Observatory, gave the address of the evening.

The methods of predicting eclipses, the information gained in observing them and some suggestions as to possible influences of sunspots on these predictions and observations were the topics dealt with by Dr. DeLury in his lecture entitled "Solar Eclipses."

The Saros, or the time of recurrence of eclipses, was known in very remote times and since eclipses were often noted by very primitive people these form a time scale by which ancient calendars are brought into relationship to our present calendar.

The accuracy with which the time of an eclipse and the position of the shadow cast on the earth can be predicted is a splendid tribute to the mathematics of astronomy, yet there are errors in time and place that are at present unexplainable. The lecturer discussed these errors in their relation to the influence of sunspots. The nature of the corona, those streamers that are the result of columns of gas expelled from the body of the sun, depends upon the state of spottedness of the sun. The brightness of comets in their successive returns was due to the same influence.

The proof of the Einstein theory was explained by the bending of star light as these rays passed the sun and by the shift of the lines in the spectrum. The use of the flash spectrum was illustrated as it is used to measure the heights of various gases in the sun's atmosphere.

Several charts were shown of the paths of the two 1930 solar eclipses. The first of these being of special interest since it may be seen as a partial eclipse at Ottawa in the afternoon of April 28. The second has little interest to northern observers as it will be seen only in the southern hemisphere.

At the eclipse of April 28, only the tip of the shadow cone falls upon the earth and hence it will be of extremely short duration and the path of totality will be very narrow. This eclipse, therefore, serves as a severe test of the accuracy of the predictions.

As a result of careful observations during many years, much valuable information has been obtained. It was in such a way that the yellow radiation of helium was found, which in turn led to a search in terrestrial sources, and finally in 1895 it was identified in the spectrum of Clèveite. Discoveries of this nature have paved the way for radioactivity investigations and the many well-known fruitful developments resulting from this work.

In concluding the lecture, Dr. DeLury referred to the total solar eclipse of August 31, 1932. Rarely do we have the opportunity of being so close to the path of totality and such a chance will not occur in this locality for some 30 years or more. At this eclipse, the path of totality passes very near to Sorel, Que., then cuts across the Maine coast between Portland and Portsmouth. It is to be hoped that as many people as possible will take advantage of this opportunity, and all amateurs should be encouraged to use whatever equipment they have available for studying this greatest of all phenomena of nature.

M. S. BURLAND, *Secretary*.

The Royal Astronomical Society of Canada

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